NASA Applications for Computational Electromagnetic Analysis

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Abstract: Computational Electromagnetic Software is used by NASA to analyze the compatibility of systems too large or too complex for testing. Recent advances in software packages and computer capabilities have made it possible to determine the effects of a transmitter inside a launch vehicle fairing, better analyze the environment threats, and perform on-orbit replacements with assured electromagnetic compatibility.

Keywords: NASA, Launch Vehicle, Fairings, On-orbit Replacement, ISEAS, FEKO, MOM, GEMACS, CST Microstripes, Reverberation Chambers, Electromagnetic Shielding, MLFMM, WIPL-D

1. Introduction

Within NASA, there are 7 Centers that participate in the Electromagnetic Environmental Effects (E3) Community of Practice (CoP). One of the CoP goals is to share modeling and simulation techniques. This paper describes the ways in which 3 of the Centers make use of CEM modeling tools.

2. Marshall Space Flight Center

The International Space Station (ISS) is comprised of modules that have been integrated on orbit. Consequently, its power bus configuration has changed many times as construction has proceeded. Additionally, as scientific payload equipment is exchanged, the power bus will continue to see changes across the service life of the ISS. Because the power bus environment is complex and dynamic, it cannot readily be tested on the ground. The Marshall Space Flight Center (MSFC) has developed the ISS

Electromagnetic Compatibility Analysis System (ISEAS) tool to allow modeling of the power bus and analytic simulation of conducted emissions (CE) and conducted susceptibility (CS) of equipment connected to the power bus.

NASA performs EMI testing, tailored from MIL-STD-461, on each individual piece of equipment. Data from CE01, CE03, CS01 and CS02 tests are input to the ISEAS software program along with the physical dimensions of power bus cabling. Recent ISEAS analyses are listed below.

Columbus Module and European Space Agency (ESA) payloads
Japanese Experiment Module (JEM)
Starboard (S6) Photovoltaic Module
Microgravity Science Glovebox (MSG) – Boiling Experiment Facility (BXF)
Environmental Control and Life Support System (ECLSS)
Waste and Hygiene Compartment
Node 2 Module

The ISEAS program performs a Root Sum Square (RSS) on both the CE01 and CE03 test data obtained from each piece of equipment in the power bus environment. It then computes the margin between the RSS calculated emissions and the specified limit listed (SSP 30237), as shown in Figure 1.

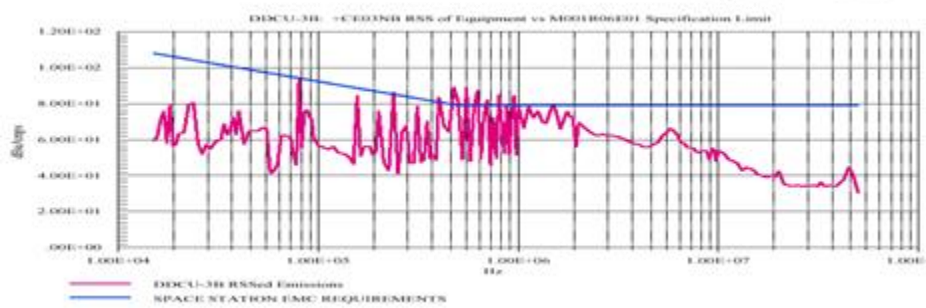

Figure 1: ISEAS Analysis Results comparing CE03 Computations to Space Station Requirements

In addition, the program computes the total power bus ripple voltage by multiplying the CE01 and CE03 test data by the bus impedance. Comparison of the computed ripple voltage with the appropriate limit yields the margin, as shown in Figure 2.

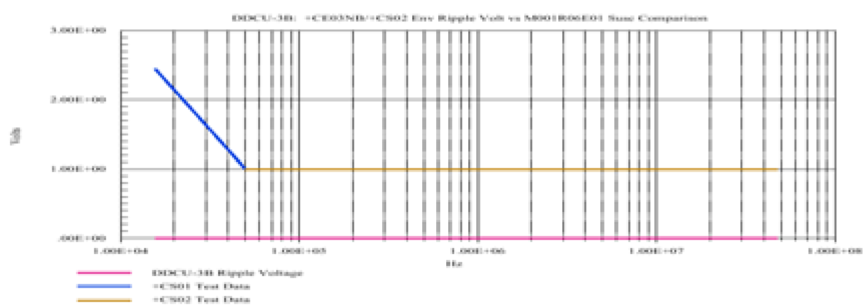

Figure 2: ISEAS Analysis Comparing Calculated Bus Ripple Voltage to Space Station Limits

3. Kennedy Space Center Launch Services Program

The primary focus of KSC Launch Services Program (LSP) electromagnetic computational analysis is fairing RF environment evaluation. These analyses are performed when there is a vehicle or

spacecraft transmitter irradiating the interior of the fairing and when a fairing shielding effectiveness evaluation is needed to evaluate the effects of external range or launch vehicle transmitters. LSP utilizes two full wave computational analysis tools for these problems. The memory requirements of most full wave techniques are prohibitive for large structures illuminated with GHz frequencies. FEKO has a multi-technique and multi-processor capability[1]. The multilevel fast multi-pole method (MLFMM) used in conjunction with the method of moments (MoM) technique allows for accurate solutions in vehicle fairing sized structures[2]. WIPL-D is also used for this purpose which also uses the MoM technique, but incorporates higher order basis functions which allow the mesh elements to be on the order of a wavelength instead of 1/10th of a wavelength [3,4]. A subscale fairing fixtures are currently being used to anchor these models with a test case [5]. Model results in Figure 3 depict cavity fields due to an internal transmitter for a single and multilayer layer fairing, while Figure 4 shows the magnetic field shielding effectiveness of a composite fairing.

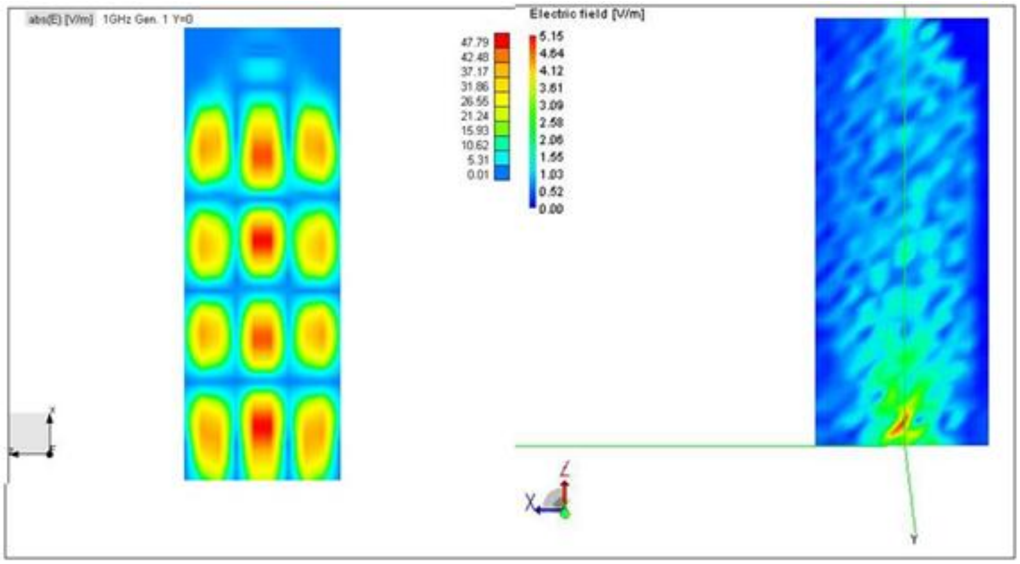

Figure 3: Field Distribution Inside Fairing Cavity at 1 GHz Using WIPL-D (left) and inside a Blanketed Cavity at 2.6 Ghz using FEKO(right)

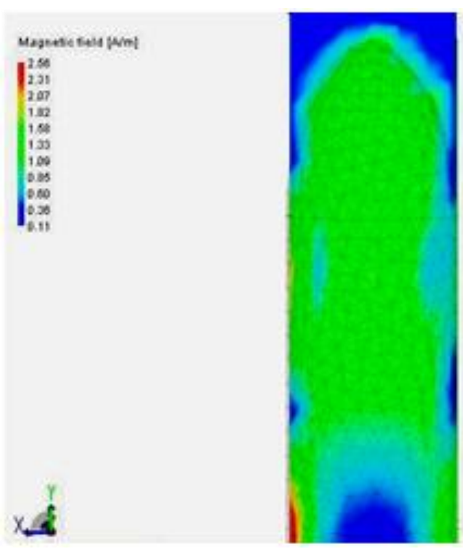

Figure 4: Magnetic Field Shielding Effectiveness with FEKO

Another area of computational analysis emphasis at LSP is lightning indirect effects evaluation. In this case a time domain transmission line matrix approach is used in CST simulation suite. A nearby lightning pulse can be modeled and then propagation through the structures of interest evaluated. Figure 5 demonstrates this transient magnetic field shielding. This is especially useful when diffusion is of interest as with composite fairings. Spice based circuit analysis tools are also valuable tools for evaluating circuit level analysis of lightning mitigation devices.

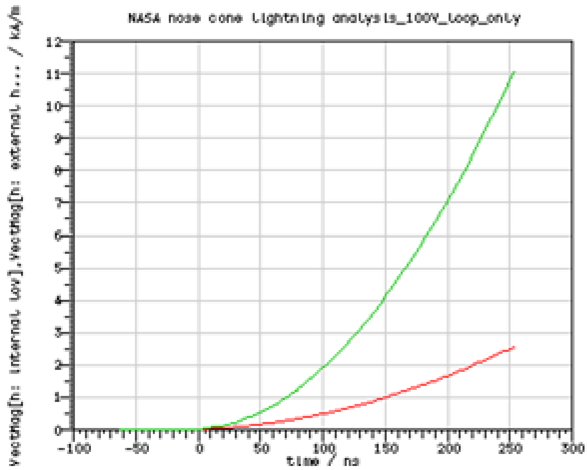

Figure 5: CST Microstripes Simulation of Transient Magnetic Fields Internal and External to Fairing

4. Glenn Research Center

Glenn Research Center (GRC) is currently involved in an effort to perform EMI testing in the Thermal Vacuum Chamber at its Plum Brook Station. Once completed, this chamber will be the world's largest reverberation chamber by quite a margin. Figure 6 shows the enormity of this chamber, which is lined with type 3003 aluminum. The doors of the inner test chamber are 50 X 50 ft., and a personnel access door allows access to instrumentation and test article between tests.

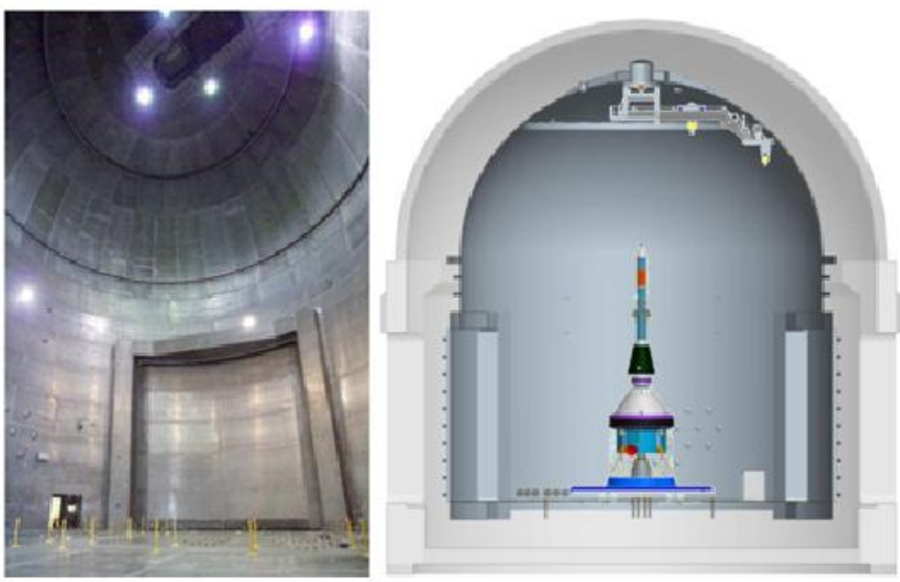

Figure 6: Side-by-Side Views of the Reverberation Chamber, with Orion Space Vehicle for Scale

Initial FDTD modeling of the chamber was compared to time domain measurements taken in the chamber by the Institute for Telecommunication Sciences (ITS). Robert Johnk, et al, describe that the model predicts strong modes below 10 MHz, and this was validated by their measurements. The computed waveforms for 200 μsec long time-domain E-fields at six chamber locations compare very well to the measurements taken at the same points with respect to shape, rates of decay, and the distinctive single-exponential decay envelope. Differences between model and measurement field amplitude might be due to the perfect symmetry and lack of diffusers in the model versus the actual chamber geometry. [6]

Subsequent frequency domain testing performed by the National Institute of Standards and Technology (NIST) revealed that it was an excellent reverberation environment over a very wide frequency range, despite the fact that reverberation chambers are not typically shaped like domed cylinders. [7] In addition, the extraordinary chamber size is expected to allow testing down to 50 MHz, compared with the 80 MHz lower limit of standard reverberation chambers. Future characterization and calibration with a mode stirrer designed by Oklahoma State University, performed by NASA Glenn Research Center with oversight by NIST, will certify the chamber and define the useable volume and lowest useable frequency.

In addition to the on-going work at GRC's Plum Brook Station, some early modeling analysis was performed in support of the Expendable Launch Vehicle Mission Analysis Group at KSC. The goal of the study was to compare two computational techniques, Method of Moments (MOM) and Uniform Theory of Diffraction (UTD), using the tool GEMACS developed by Dr. Edgar L. Coffey, now of Applied Research Associates, Inc. For the study, a fairing, spacecraft, spacecraft support structure, and antenna were modeled. This analysis comparison was completed in 2005, in the early days of Dr. Coffey's CEM FrameWork tools.

The fairing was modeled in two ways, one with a UTD model and another with a MOM model. The launch vehicle fairing body was modeled by a cylinder, approximately 4 meters in diameter by 7.25 meters tall, joined with a conical shape, and covered with a plate. Figure 7 shows the two different models.

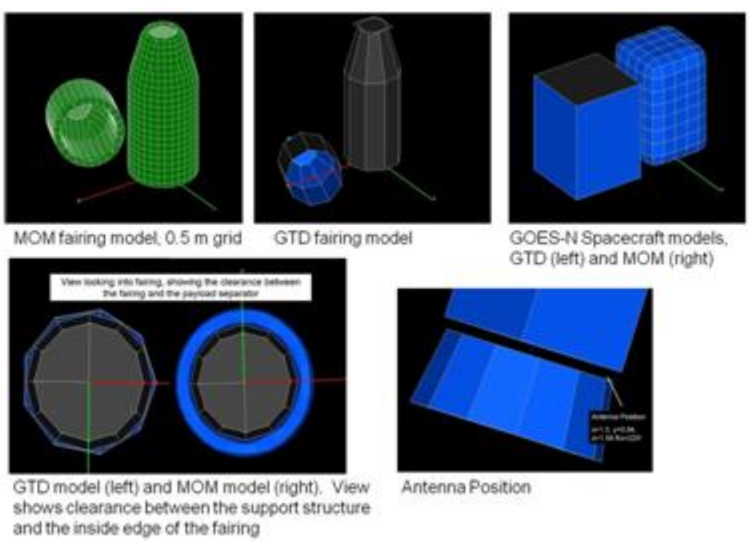

Figure 7: MOM and UTD (GTD) Models of Fairing, Spacecraft, Separation Plane, and Antenna

Variation in solutions between MOM and UTD were evident, however, computational resource constraints limited the number of bounces in the UTD solution as well as the mesh size in the MoM solution. The analysis served as an exercise to gain confidence in the validity and usefulness of the

process. GRC will pursue future modeling efforts to predict and validate electromagnetic compatibility of NASA systems from the card level up to the system level.

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